

The Application of Ultraviolet Germicidal Technology in HVAC Systems

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Introduction

One of the most significant issues for today's HVAC (Heating, Ventilation, and Air Conditioning) engineer is Indoor Air Quality (IAQ). Many building owners, operators, and occupants complain of foul odors emanating from HVAC systems.

The objectionable odor is the byproduct of the microbial growth (mold and fungus) that accumulates and develops on wet surfaces of HVAC units, causing foul odors to emanate from affected systems and degrading the IAQ and unit performance.

This objectionable odor has been appropriately named the "Dirty Sock" syndrome.

Less obvious to the building occupants, but of equal importance, are the physical effects the microbial organisms have on HVAC equipment. They restrict the airflow and limit the heat transfer capability, which increases the operating costs of the equipment.

Fortunately, IAQ degradation, foul odor, and increased expenses can be eliminated with the installation of the ultraviolet 'C' band (UV-C) lamps. The ultraviolet germicidal lamps are designed to kill odor causing mold and fungus that grow in wet evaporator sections of HVAC units. These lamps are installed inside HVAC systems and irradiate areas inhabited by the offending organisms, making it impossible for them to survive. The organisms disappear, the odors disappear, and most importantly, the IAQ complaints disappear.

This guide will discuss the microbial growth and IAQ contaminant problems in the HVAC industry, the UV-C lamp and other possible solutions, and the benefits of using the HVAC Duty UV-C lamp.

What is Ultraviolet-C?

Ultraviolet-C (UV-C) is one form of electromagnetic energy produced naturally by the sun. Artificially produced UV-C energy aids in enhancing Indoor Air Quality (IAQ) by eliminating microbial organisms that grow on wet surfaces of HVAC systems.

Electromagnetic Spectrums

The sun, a thermonuclear reactor system, produces a spectrum of electromagnetic energy which ranges from cosmic rays to radio waves. We are casually aware of portions of this electromagnetic spectrum, such as the infrared portion, which warms the earth, and the visible light portion to which our eyes respond allowing us to see. Ultraviolet energy is also a portion of the sun's electromagnetic spectrum. The UV region (excluding vacuum UV) is defined as that portion of the electromagnetic spectrum with wavelengths between 200 and 400 nanometers (nm). UV-C, also known as "Short Wave UV," has wavelengths of between 200 nm and 290 nm (Fig. 1).

Types of UV Electromagnetic Energy

The use of various forms of UV energy is quite common in our everyday lives, some of which require special care when used since they can be potentially harmful. It is therefore important to be familiar with these forms of UV energy, their uses, and their dangerous effects on humans when not handled properly. Three forms of UV energy are discussed below.

UV-A energy is the primary energy component used in tanning beds. UV-B energy is used as a treatment for skin conditions such as psoriasis. Prolonged exposure to UV-A and UV-B energy can lead to skin cancer and has been shown to contribute to the incidence of cataracts.¹ UV-C energy, when used with the proper safeguards, is relatively harmless to humans, although prolonged exposure may cause temporary reddening of the skin and/or temporary conjunctivitis.

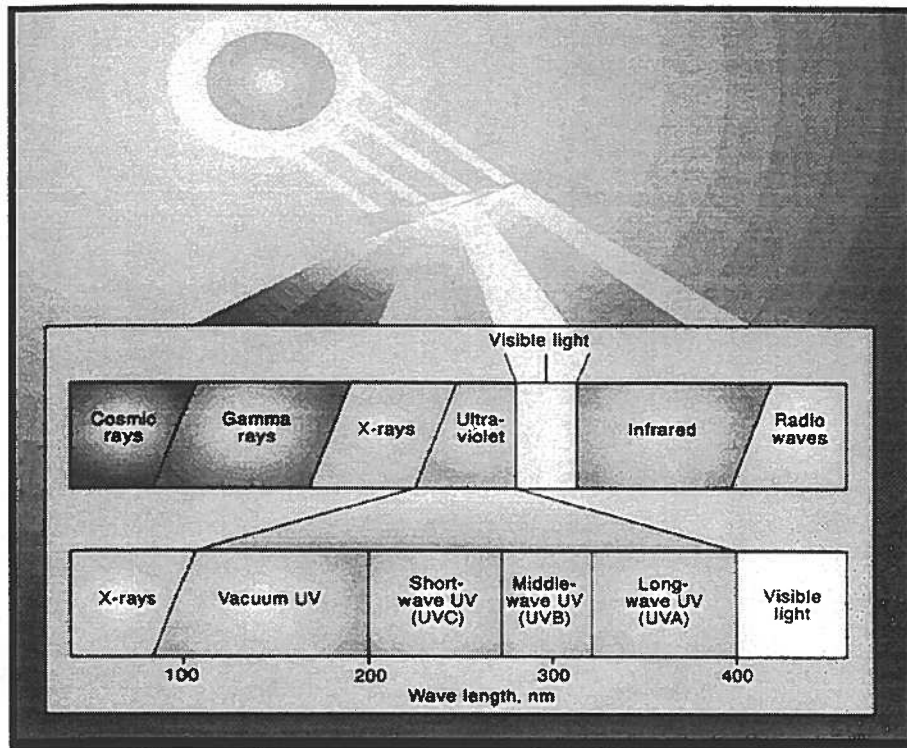


FIG. 1 — SOLAR ENERGY

Absorption and Scattering Processes

As stated previously, the sun emits a variety of energy forms, some forms of which are harmful to the complex molecules necessary for earth's lifeforms. The harmful forms are the ultra short-wave radiation that includes X-rays, gamma rays, and ultraviolet radiation. Due to the distance between the earth and the sun, only some of the energy emitted by the sun reaches the earth's surface, minimizing the intensity of harmful particle radiation. Fortunately, the distance is appropriate for the infrared and visible light necessary for photosynthesis and life as we know it.

Solar energy that reaches the earth's atmosphere interacts with the molecules in the atmosphere by the processes of absorption and scattering. In the process of absorption, molecules absorb the solar energy and convert it to heat. In the scattering process, solar energy is reflected by gas molecules, dust particles, and water vapor. The blue color of the sky is due to the scattering process. Shorter wavelength (blue) light is scattered more effectively than the longer wavelengths, making the sky appear blue.

Figure 2 compares the amount of solar energy reaching the earth's atmosphere to the amount that actually penetrates to the earth's surface.

Absorption and the Ozone

The ultraviolet radiation that reaches the upper atmosphere is also impacted by the absorption process. A key component in absorption of ultraviolet energy is ozone (O_3) in the upper atmosphere. Oxygen (O_2) from the upper atmosphere absorbs ultraviolet energy with a wavelength less than 242 nm (UV-C and Vacuum UV). The result is the dissociation of the O_2 molecule, allowing the formation O_3 . The O_3 in turn absorbs ultraviolet energy with wavelengths 242 nm to 320 nm (UV-C and UV-B) converting the O_3 back to O_2 and O . This continual process limits the amount of potentially damaging ultraviolet energy reaching the earth's surface to very low levels.

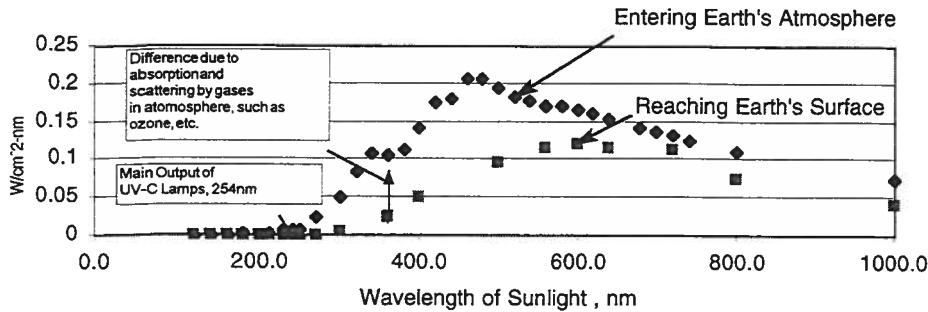


FIG. 2 — SOLAR RADIATION ENTERING EARTH'S ATMOSPHERE AND REACHING ITS SURFACE

UV-C Usage

When ultraviolet light is used on the earth's surface correctly and with appropriate safeguards, it can be extremely beneficial as a germicidal tool. The germicidal effects of ultraviolet light were first noticed and actively studied by a Danish physician, Niels Ryberg Finsen (1860-1904), in the 1880's. Dr. Finsen had noticed a connection between exposures to the sun's rays and a stimulating effect on human tissue. His work led to the development of the Finsen curative lamp, a device that produces artificial "sunlight." This "sunlight" also contained UV light. The Finsen curative lamp remained in use as a healing aid through the 1950's (Fig. 3). The key portion of Dr. Finsen's discovery was that light, ultraviolet light, has the ability to destroy pathogenic organisms.² The importance of Dr. Finsen's work was recognized in 1903 when he was awarded the Nobel Prize for Medicine.

Today we recognize that ultraviolet light, specifically UV-C with a wavelength of approximately 260 nm, has a pronounced germicidal effect. We have also learned that mercury has a natural spectral line of 253.7 nm and if vaporized in plasma will emit UV-C energy at approximately 254 nm. These discoveries lead to the development of the first commercial UV-C germicidal lamps by the lamp division of Westinghouse in the 1930's. The Westinghouse lamps were used primarily in hospital environments through the 1950's. The challenge today is to utilize the germicidal capability of UV-C energy in the HVAC industry.

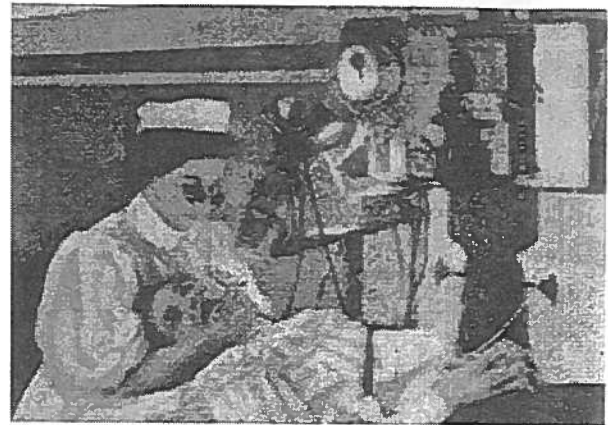


FIG. 3 — FINSEN CURATIVE LAMP

UV-C Benefits and the IAQ Problem

To fully understand the potential for UV-C energy as a tool in the IAQ struggle, it is appropriate to briefly examine the IAQ issue and the attempts to define "quality air." ASHRAE standard 62-1989 (Fig. 4) defines quality air as, "Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

A synonym for "quality air" may be "fresh air." Fresh air is sometimes considered to be synonymous with outside air. Outside air, dependent upon the location, may vary considerably from the accepted chemical composition for fresh air. To add further complexity, the air supplied by the HVAC system, i.e., supply air, is typically a mix of outside air and air returned from the conditioned space, i.e., return air. The key point is that indoor air is comprised of air from many sources and the determination of the quality of the air is very subjective.

As difficult as it may be to quantify quality air, there seems to be some agreement as to what constitutes an IAQ problem. In all situations where IAQ is deemed a problem, three factors are present: a source of contamination, susceptible occupants, and a mechanism to transport the contaminants. Examples of sources of contamination are the building, its furnishings, its occupants, and the outdoors. The susceptible occupants are individuals occupying the building and the transport mechanism is the HVAC system that circulates large volumes of air.

The IAQ problem is analogous to a three-leg stool with the three legs of the stool representing each of the three factors of the IAQ problem. Remove any one leg of the stool, the stool collapses, and the IAQ problem disappears.

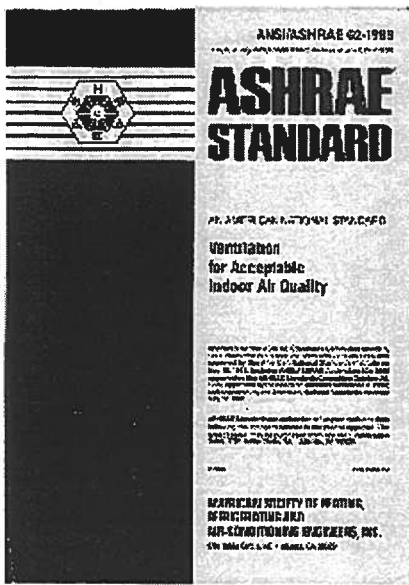


FIG. 4 — ASHRAE STANDARDS

Identification of IAQ Contaminants

Contaminants may be categorized as gases or particles.

Gases

The gases include volatile organic compounds, (VOCs). Organic compounds classified as aldehyde compounds generally represent a prominent fraction of the VOCs presence. Formaldehyde and acetaldehyde are commonly recognized aldehyde vapors. Potential VOC sources are off-gassing from the building furnishings, e.g., carpets, furniture, etc., and life

cycle byproducts of microorganisms living in the building (or its HVAC system). Aldehydes are typical byproducts of both off-gassing and chemical processes, which occur inside or outside of the building. VOCs are of particular concern because many people exhibit reactions even when the VOC levels are below established permissible exposure levels (PEL). The most common symptoms related to VOC sensitivity are irritation of the eyes, nose, or throat.

Particles

The classification of a contaminant as a particle or a large molecule can sometimes be difficult, we can arbitrarily define a particle as any species with a diameter of 0.1 micrometer or greater, whereas large molecules are less than 0.1 micrometer in diameter. Viruses, for example, range in size from about 0.05 micrometers to slightly larger than 0.1 micrometers, and viruses are popularly referred to as particles. Bioaerosols are defined as airborne particles, which are living organisms, spores, or fragments of organisms released from living organisms. The bioaerosols include pathogens (disease causing viruses, fungi [mold], and bacteria), allergens (fungi [mold] and bacteria which initiate allergic reactions), and toxins (mycotoxins and endotoxins). Aerodynamically, the bioaerosols tend to behave like gases, i.e., they float in the air, are induced to move by thermal gradients, and may remain suspended for hours.

Where do these bioaerosols come from? Unfortunately, modern buildings provide a haven for them. The fungi will propagate in dark, damp areas. A relative humidity of only 30% will provide adequate moisture for fungus growth. A visual indicator of the presence of fungi is mold. Mold is a byproduct of the fungi and is typified by a green/gray color and a musty smell. Bacteria are most likely to flourish in standing water and have been known to exhibit the dirty sock odor. Humans also contribute bioaerosols to the atmosphere. Sneezing and nose blowing are the major source of aerosolized viruses in a building. A single sneeze may produce 100,000 pathogen-containing droplets of moisture.⁴ These droplets, known as "Fomites," will remain suspended for lengthy periods of time and are circulated by the HVAC system.

In short, the types of contaminants are diverse and come from a multitude of sources. The common factor with all of these contaminants is that some may be circulated by the HVAC system.

Sources of Contamination

Of particular concern is the contamination of the HVAC system with bioaerosols. The requisite needs for biological contamination are a source of water, a nutrient base, and an initial seeding of bioaerosols. The number of bioaerosols required for contamination may be very small; in fact only a microscopic quantity is needed. The sources of these bioaerosols may be external to the building or from within the building itself. Bioaerosols enter the HVAC system through its air intakes. Various forms of fungi exist outdoors and typically enter the HVAC system through the fresh air intakes in the form of spores. The spores are very hardy and may lie dormant for long periods of time waiting to flourish under the proper environmental conditions. The indoor environment, which is warm and protected from sunlight, creates an environmental niche for viruses and bacteria that could not otherwise survive for long outdoors. The spores propagate releasing additional spores to the interior environment creating what is known as the Amplifying Effect. It is not uncommon for the number of spores in the return air to exceed the outdoor levels.

Small animals, rodents, and birds can transport a diverse mix of environmental bacteria and various pathogenic organisms to the HVAC system through the return air stream.

Climatic conditions are also a factor in HVAC system contamination. Fungi exist virtually everywhere but are especially abundant in hot climates. When the soil is dry, windy conditions will readily disturb the soil, and the air currents will carry the spores and bacteria to the HVAC intakes.

Today's HVAC operating conditions may also contribute to the level of contamination.

Prior to the energy crisis of the mid 1970's, the typical HVAC system operated continuously, with constant airflow. Moisture, which condensed on the coil and flowed to the drain pan, would re-evaporate in the constantly moving air. As a result, the coil surfaces and drain pan remained dry most of the time. Post energy crisis operation has changed to one in which the airflow is variable through the use of variable air volume (VAV) systems, timeclocks that cycle the units ON/OFF, and variable frequency drives (VFDs) that vary the fan speed. The variable airflow allows the coil and

drain pan to collect moisture, providing an ideal growth environment (dark, warm, and moist) for fungi, bacteria, and viruses.

In the past, coil and drain pan cleaning may have been performed as often as once a week. Today, according to the Building Owners and Managers Association (BOMA), the average cleaning is only 3.5 times per year. The change in operating methods combined with the changes in maintenance practices have resulted in a man-made environmental niche that supports the growth of bioaerosols. This niche is the perfect breeding ground for bioaerosols. An average cell division rate for molds and bacteria is once every 120 minutes. At this rate a single organism deposited on the damp, warm coil could multiply to 5.7×10^{17} (570,000,000,000,000,000) organisms in one week!

Contaminant Effects on HVAC Systems

The effects on the HVAC system are twofold. The first is performance degradation. The millions of organisms that grow on the coil surface restrict the airflow through the coil resulting in decreased equipment performance and higher operating costs. The organisms on the fin surfaces also reduce the heat transfer capability of the coil, resulting in decreased performance and higher operating costs.

The second effect is on indoor air quality. Fungi, bacteria, and viruses are flourishing in this man-made niche. When the HVAC system is operating, the large volumes of air moving throughout the structure carry these bioaerosols into every section of the building. The HVAC system has become a host and an amplifying factor for a "source" in the IAQ problem.

Solutions for HVAC Contaminants

Fortunately the solution is simple. Utilize ultraviolet germicidal irradiation (UVGI) to kill contaminants in the HVAC system. Install man-made sources of UV-C energy in the HVAC system to help eliminate a "source," and the IAQ three-leg stool collapses.

Ultraviolet Germicidal Irradiation

UV-C energy when applied in the proper manner has the ability to prevent biological growth. UV-C

energy is capable of breaking molecular bonds disrupting the cellular growth of the target organism.⁵ UV-C energy alters the DNA of the organism, preventing reproduction and multiplication. The key to UVGI is to apply a chronic dose of ultraviolet energy that kills 99.9% of the target organism(s).

The output of an UV-C lamp is expressed in microwatts/cm² measured at a distance of one meter from the bulb. To evaluate the output energy at distances different than 1 meter, the "intensity factor" is used.⁶ The Intensity Factor Calculation table below depicts how the distance from the lamp to the target determines the intensity factor.

INTENSITY FACTOR CALCULATION

Intensity Factor	
Distance inches	Intensity Factor
2	32.3
3	22.8
4	18.6
6	12.9
8	9.85
10	7.94
12	6.48
14	5.35
18	3.6
24	2.33
36	1.22
39.37 (1 m)	1
48	0.681
60	0.452
80	0.256
100	0.169
120	0.115

The dose applied by an UV-C lamp installation is a function of the lamp output, the intensity factor, and time. The equation may be stated as:

$$\text{Dose} = \text{Lamp output at 1 meter} \\ (\text{microwatts/cm}^2) \times \text{Intensity} \\ \text{factor} \times \text{Time (sec.)}$$

The dose required to kill a given microorganism is given in units of microwatt-seconds/cm².

Figure 5 details the dose required for disinfection (90% kill) and sterilization (99.9% kill) for a variety of common mold spores (fungi).^{7, 8, 9, 10}

The time required to kill 99.9% of a given organism is expressed by the formula:

$$\text{Time} = \text{Required Dosage} / (\text{Lamp Output at 1} \\ \text{meter} \times \text{Intensity Factor})$$

Figure 6 indicates the time required for sterilization of *Penicillium expansum*, one of the most common indoor spores, when the lamp is placed 8 inches away from the target.

$$\text{Time} = \text{Required Dosage} / (\text{Lamp Output} \times \\ \text{Intensity Factor})$$

$$\text{Time} = 22,000 \text{ microwatt sec/cm}^2 / (120 \\ \text{microwatt/cm}^2 \times 9.85) \\ \text{Time} = 18.6 \text{ seconds}$$

In 18.6 seconds, 99.9% of the *Penicillium expansum* organisms will be dead.

The next question is how do we best utilize this potent UV-C energy to apply a fatal dose to these biological contaminants?

Since UV-C energy requires a finite amount of time to effect a kill, it's ideally suited to treat static contaminated surfaces - like the damp evaporator coil and condensate pan inside an HVAC unit. One of the best locations for the HVAC duty UV-C germicidal lamps is on the leaving air side of the evaporator coil over the condensate pan so that both areas are irradiated simultaneously. HVAC units using evaporator coils that are very deep may require lamps installed on both sides of the coil for best effectiveness. In either case, following the sizing guidelines appearing later in this guide will assure more than enough UV-C dosage to sterilize the target area.

Attempting to treat "fly-by" contaminants entering the HVAC unit from either the return air system or ventilation air is not practical with current technology. The problem with "fly-by" control is the time required to affect a kill and the distance traveled by the contaminant in that time period. Consider the foregoing example of *Penicillium expansum*. If the air in the ductwork is traveling at 400 ft per minute, in 18.6 seconds the target organism will have traveled 124 feet. This means, at the flux density of the HVAC duty UV-C germicidal lamp, a bank of UV-C lamps 124 feet long would be required to affect a 99.9% kill. Obviously this is not practical at this time.

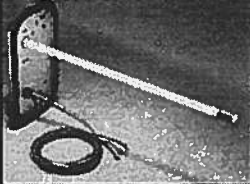
Indoor Air Quality			
UV-C ENERGY DOSAGE NECESSARY FOR DISINFECTION AND STERILIZATION			
Mold Spores	Color	UV-C Energy Dosage (Microwatt sec/cm ²)	
		90%	99.9%
Penicillium roqueforti	Green	13,000	26,400
Penicillium expansum	Olive	13,000	22,000
Penicillium digitatum	Olive	44,000	88,000
Aspergillus glaucus	Blue green	44,000	88,000
Aspergillus flavus	Yellow green	60,000	99,000
Aspergillus niger	Black	132,000	330,000
Rhizopus nigricans	Black	111,000	220,000
Mucor racemosus A	White grey	17,000	35,200
Mucor racemosus B	White grey	17,000	35,200
Oospora lactis	White	5,000	11,000

FIG. 5 — UV-C DOSAGE REQUIREMENTS

Indoor Air Quality

HOW EFFECTIVE IS IT?:

Time = Required Dosage / (Lamp Output x Intensity Factor)



Power Output @ 45F
120 Microwatt/cm² @ 1 m

Intensity Factor	
Distance inches	Intensity Factor
2	32.0
3	22.8
4	18.6
5	14.9
6	12.5
8	9.65
10	7.64
12	6.48
14	5.35
16	4.6
24	2.93
36	1.55
39.37 (1 m)	1
48	0.681
60	0.409
80	0.215
100	0.139
120	0.117

To achieve 99.9% kill of Penicillium Expansum, a dosage of 22,000 Microwatts.Sec/cm² is reqd.

The UV-C emitter shown above, at a range of 8 inches, will accomplish this in 18.6 seconds.

FIG. 6 — UV-C TIME REQUIREMENTS

Biofilm Source Control - Method and Benefits

One of the most beneficial uses of UV-C lamps in a HVAC system is as a surface treatment device. This method is called "biofilm source control." In this application the bioaerosols on the evaporator coil or in the drain pan will be killed at the source. Therefore the offending bioaerosol will not have the opportunity to enter the ducts, the terminal devices, or the building itself. Installation of UV-C lamps in new systems will ensure that the performance loss associated with bioaerosol contamination of the coil and drain pan cannot occur. In existing systems the performance impact of the bioaerosols will be reversed and eventually eliminated. The irradiation of the coil surface and drain pan will ultimately kill all of the organisms. The organisms will decay and be carried away in the condensate water. Initially the UV-C energy will kill the organisms on the surface. In the case of the

coil, as the organisms disappear from the surface, the UV-C energy will be able to reach deeper and deeper into the coil, reflecting from fin to fin, ultimately destroying the organisms throughout the coil. In the case of the drain pan, if standing water exists, the UV-C energy will kill the organisms at or near the surface of the water first. The UV-C energy will not penetrate below the surface of the water, but over a period of time movement of the organisms in the water will cause the organisms to move to the surface and be killed. The typical result is a return of the coil and condensate pan to an "as installed" condition. Coil pressure drop typically will also return to "as installed" levels (excluding losses due to normal system aging) with the accompanying reduction in fan energy requirements. Figure 7 depicts the improvements noticed during a 30-day period following the retrofit of a 20-year old air handler with HVAC duty UV-C germicidal lamps.

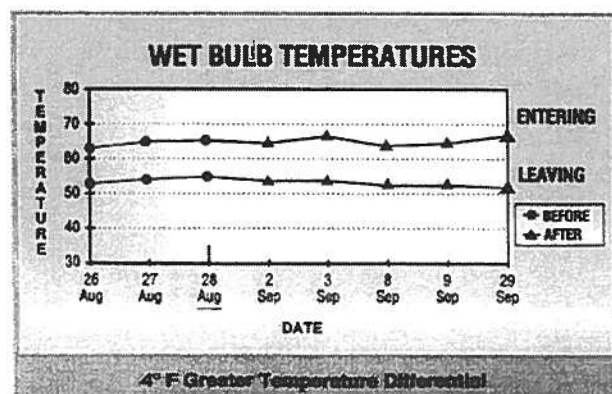
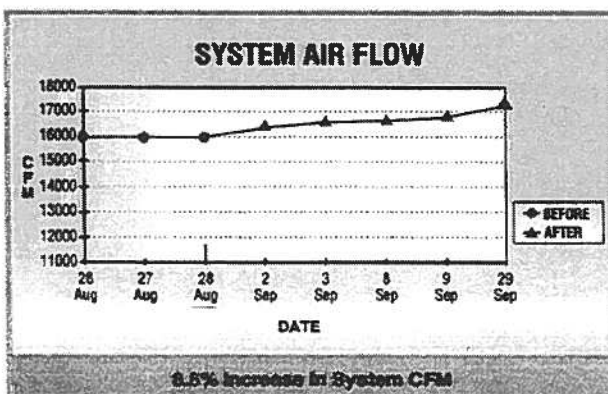
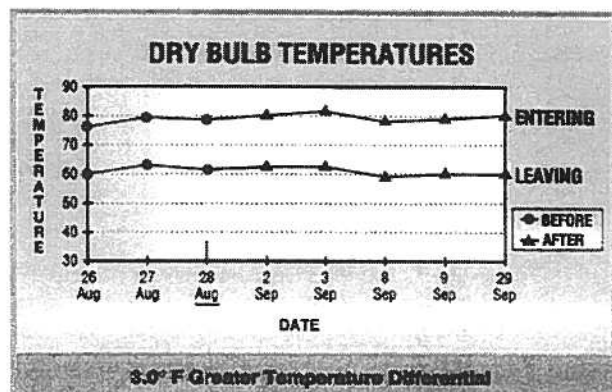
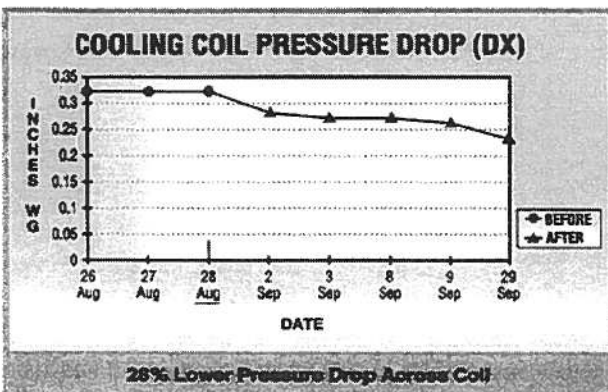


FIG. 7 — HVAC IMPROVEMENTS WITH UV-C LAMP INSTALLED

The benefits will also be obvious in reduced maintenance costs. The need for coil cleaning due to the buildup of bioaerosols will be virtually eliminated. In the presence of UV-C energy the mold will not develop.

Other forms of coil cleaning may only clean the visible surface of the coil. In fact, pressure washing of coils may compact the "dirt" deep inside the coil resulting in increased coil restriction. The reflective nature of the UV-C energy allows it to keep the coil clean from surface to surface. Drain pan restrictions are also reduced. Typical condensate drain blockages result from what appears to be "hair." Quite often the maintenance worker is perplexed as to the source of all of this "hair." Once again, this "hair" is most likely mold that cannot exist in the presence of UV-C energy.

The necessity for routine duct cleaning may also be reduced. Mold growing in the ductwork typically develops from spores that were introduced into the HVAC system. If the spores are killed at the coil area, they will never have the opportunity to grow into mold. However, the installation of UV-C lamps in the evaporator section of the HVAC system will not affect existing mold in the ducts.

The single most obvious advantage of the use of UV-C energy in the HVAC system is the IAQ improvement perceived by the building occupants. The "Dirty Socks" odors that are typical when bioaerosols are flourishing in the HVAC system have been found to disappear with the application of UV-C lamps. Discoloration of ceiling air terminals due to a buildup of mold and spores is reduced. These improvements typically occur in a matter of days. The result is that the comfort level of the building occupants increases dramatically. Increased occupant comfort may be connected to improved attendance and increased employee productivity. The financial benefits associated with productivity gains and reduced needs for temporary or substitute workers can be significant over time.

Other Methods for Bioaerosol Control

Certainly there are other approaches to control of bioaerosols in the HVAC system. However, each of these methods may have disadvantages, which UV-C energy does not have.

Chlorinated cleaning agents and biocides have been known to off-gas objectionable chemicals and/or odors to the occupied space. Biocides in particular are limited by the "Dead Body Effect." The biocide must physically come into contact with the target organism in order for a kill to occur. Once a layer of "dead bodies" develops between the biocide and the target, the biocide may lose its effectiveness.

High Efficiency Particulate Air (HEPA) filtration is another alternative. HEPA filters have the ability to intercept many fungal spores. However, they also intercept nutrients, and if damp, provide a site for the spores to grow and multiply. The spores may grow through the filter material, releasing spores on the downstream side of the filter.¹² The result is that the filter contributes to the increase in the number of spores in the occupied space rather than decreases them. HEPA filters are unable to remove viruses. Typical HEPA filters are designed for removal of particles 0.3 microns and larger. Common viruses have a diameter of 0.2 microns or less. Viruses such as Adenovirus, Influenza, and Rhinovirus, which are responsible for colds and flu, have a diameters as small as 0.02 microns. Viruses pass through HEPA filters unimpeded. UV-C has the flexibility and operating characteristics to suit any application without the disadvantages associated with biocides, cleaning agents, or special filtration.

HVAC Duty UV-C Germicidal Lamp vs. Other Commercial UV-C Lamps

The best utilization of UV-C technology for HVAC systems is in "biofilm source control." Use UV-C energy to eliminate the source of many contaminants, thereby collapsing the IAQ three-leg stool. For this application, downstream of the cooling coil, the UV-C lamp must be able to provide maximum dosage of UV-C energy at 45 to 55° F temperatures in a rapidly moving airstream - a job ideally suited for the HVAC duty UV-C high output, low temperature duty germicidal lamps. It is important to understand that not all commercially available UV-C lamps are suitable for use in a HVAC system. Many commercially available UV-C lamps are designed for optimal performance at room temperature and allow significant power reduction at lower temperatures. Lamps of this type are not suitable for use in the damp, cool, moving airstream environment found in the HVAC system. The HVAC duty UV-C germicidal lamp

uses a blend of inert gases in the bulb and a specialized power supply that maintains the optimal plasma temperature inside the bulb even in a low temperature, moving airstream. This combination results in a UV-C lamp which provides its maximum power output at 45° F and 400 fpm, perfect for use in an HVAC system. Equally important, the mixture of gases used creates a bulb which does not produce UV with wavelengths of less than 200 nanometers. Therefore the HVAC duty UV-C germicidal lamp does NOT contribute to the production of ozone.

One of the key factors in providing a sterilizing dose of UV-C energy is lamp output. By providing a lamp that has its highest output at low temperatures, HVAC duty UV-C germicidal lamps will kill the target organisms in the shortest period of time. See Fig. 8 for a graphical comparison of HVAC duty UV-C germicidal lamps vs. conventional lamps.

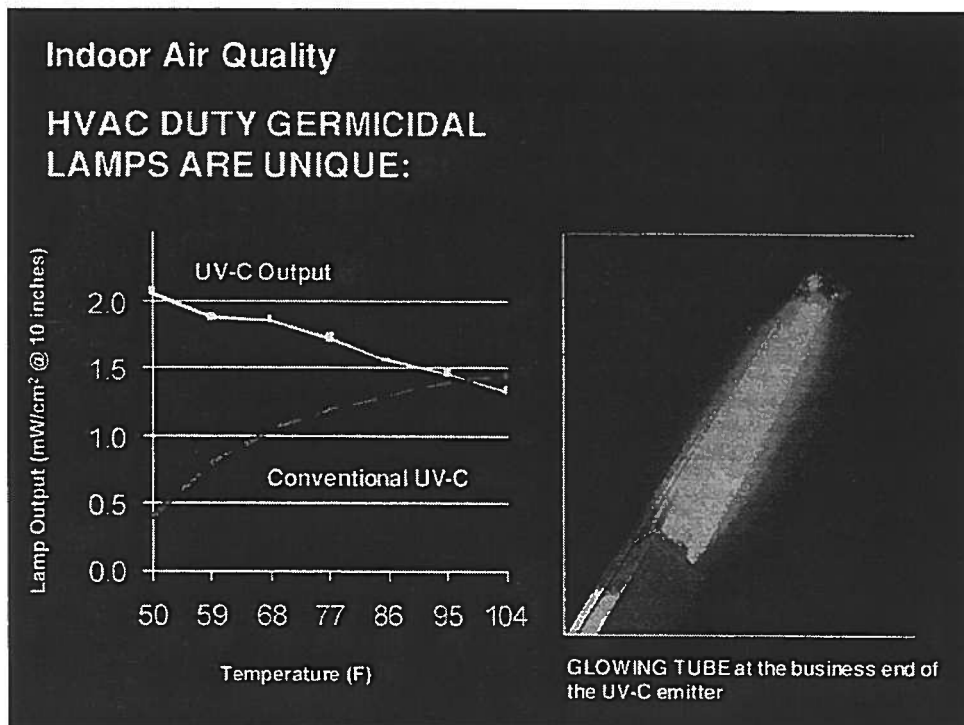


FIG. 8 — HVAC-Duty UV-C GERMICIDAL LAMP OUTPUT RESULTS VS. OTHER COMMERCIAL UV-C GERMICIDAL LAMP OUTPUT RESULTS

Application of HVAC Duty UV-C Germicidal Lamps to HVAC Systems

The intended use of the HVAC Duty UV-C germicidal lamp is to target organisms that cause the IAQ problem known as "Dirty Socks." The "Dirty Socks" odor has been found to be the result of the growth of mold in the HVAC system. To eliminate this growth of mold, it is important to use the proper number of lamps per square foot of target surface, i.e., coil surface and drain pan surface. The Guidelines for the Area to be Treated by a Single UV-C Bulb table details the amount of surface that can be effectively irradiated by a single bulb based upon the distance from the bulb to the target surface. Note that the recommendation is different for new installations vs. retrofit applications. Retrofit applications may require more lamps to remediate the surfaces in the shortest possible time.

GUIDELINES FOR THE AREA TO BE TREATED BY A SINGLE UV-C BULB

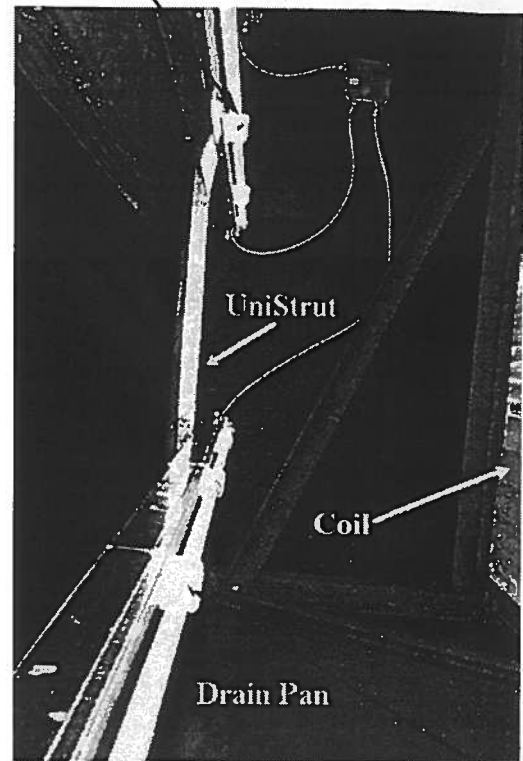
Distance Bulb to Target	New	Retrofit
8 to 12 inches	16 ft ²	12 ft ²
13 to 16 inches	8 ft ²	6 ft ²
17 to 24 inches	4 ft ²	3 ft ²

HVAC Duty UV-C Germicidal Lamp Location

The best location for the lamps is on the downstream side of the coil, evenly spaced across the coil, within 13 to 16 in. of the target surface(s). The downstream location is selected because the downstream side is the wettest portion of the coil and typically the largest portion of the drain pan is on this side of the coil. Figure 9 shows a typical installation.

Note: The fixtures are UL (Underwriters' Laboratories) and CSA (Canadian Standards Association) listed for outdoor and damp location use.

HVAC DUTY UV-C GERMICIDAL LAMP



HVAC DUTY UV-C GERMICIDAL LAMP

FIG. 9 — HVAC DUTY UV-C GERMICIDAL LAMP LOCATION

General Installation Guidelines

1. Determine the number of lamps required (see Guidelines for the Area to be Treated by a Single UV-C Bulb table page 19) and a suitable location.
2. Provide a source of single phase power (50 or 60 Hz), with a disconnect. On units with access doors, install a door interlock switch to turn off power when door is opened.
3. On retrofit installations, clean the coil prior to lamp installation.
4. Install lamps per manufacturer's installation instructions and all applicable codes.
5. Optional: Install a non UV-C penetrating glass inspection window to allow a view of the irradiated area when the lamp(s) is on.

It is recommended that the UV-C lamps are “ON” at all times and not cycle with the fan or the HVAC system. The most opportune time for growth of fungi and mold is when the air is still (the fan is “OFF”); therefore it is important to irradiate the surface at all times. The energy consumed is only 70-75 watts per lamp.

Protecting Man-Made Materials from UV-C Energy

UV-C energy does have the ability to hasten the aging process of certain man-made materials (plastics). For this reason, any wiring which does not have UV-resistant insulation or other man-made materials should be protected from the UV-C energy. This is easily accomplished by shielding the wiring or other component, with foil tape, metal conduit, or sheet metal. In regard to drain pans constructed of man-made materials, accelerated testing of materials commonly used in drain pans has been conducted. To date, the equivalent of many years of continuous exposure has produced no damage. A common question is, “What effect will UV-C energy have on the filters?” Typically the filters are located upstream of the coil and the UV-C lamps are on the downstream side of the coil. For this reason very little of the UV-C energy reaches the filter surface. If filter degradation is a concern, glass media filters using polyester backing are the most resistant to UV energy.

Maintenance and Cleaning Recommendations

Maintenance is minimal with no manual cleaning requirements. The bulbs are self-cleaning under normal usage conditions. No periodic cleaning is required due to their high power output and electronic ballast. Any organic material that lands on the bulb will rapidly disintegrate and fall off.

Since the efficiency of the lamp degrades over time it is recommended that the bulbs be replaced annually. The “glass” portion of the bulb is heavy wall 100% quartz and should not be touched by unprotected human hands. Handle the bulb with the same caution as a quartz halogen automotive headlamp bulb using clean gloves or other suitable protection. Grasp the ceramic portion at the base of the bulb. If unprotected human hands touch the quartz portion of the lamp it will require cleaning to remove the oily residue left behind. Clean by wiping the bulb with 99% pure alcohol and lint-free cloth. Disposal of the bulbs should be in the same manner as a fluorescent lighting tube.

Summary

UV-C energy is safe and beneficial when used properly. In HVAC applications the UV-C energy is contained inside the HVAC system. In this location it does not present a potential hazard to humans because the UV-C energy will never reach the occupied space of the building.

An UV-C lamp has tremendous potential as an IAQ tool. It provides a low cost, simple to install, flexible method of attacking the “Dirty Socks” problem. Apply UV-C as a biofilm source control device and help eliminate the “source” leg of the IAQ three-leg stool. Eliminate the environmental niche in the HVAC system that is promoting the proliferation of mold and attack one of the sources of the “Dirty Socks” problem. UV-C energy is a major part of the IAQ solution.

References

1. M. Tevini, editor: "UV-B Radiation and Ozone Depletion: Effects on humans, animals, plants, microorganisms, and materials" Lewis Publishers, Boca Raton, (1993)
2. The Nobel Foundation, "Biography of Niels Ryberg Finsen," <http://www.nobel.se/laurates/medicine-1903-1-bio.html>
3. ASHRAE, "Ventilation for Acceptable Indoor Air Quality," American Society of Heating, Ventilating, Refrigerating, and Air-Conditioning Engineers, Inc, Atlanta, Ga.
4. Kowalski, W.J. & Bahnfleth, W., "Airborne Respiratory Diseases and Mechanical Systems for Control of Microbes", HPAC Heating/Piping/Air Conditioning (July 1998)
5. Ultraviolet Germicidal Irradiation, Aerobiological Engineering, The Pennsylvania State University, <http://www.engr.psu.edu/ae/wjk/wjkuvgi.htm>
6. Scheir, R. & Fencel, Forrest, "Using UVC Technology to Enhance IAQ", HPAC Heating/Piping/Air Conditioning (February 1996)
7. Luckiesh, M. , Application of Germicidal, Ethyemal and Infrared Energy, D. Van Nostrand, New York, N.Y. (1946)
8. Hallaender, A. & Oliphant, J.W., Journal of Bacteriology, Volume 48, (1948)
9. Disinfection by UV-Radiation, Phillips Lighting Corporation (undated) and cited references therein
10. First, M.W., Nardell, E.A., Chaisoon, W., & Riley, R., ASHRAE Transactions, Volume 105, Part 1 (Chapter 99-12-1, 99-12-2) and and cited references therein
11. Kowalski, W.J. & Bahnfleth, W., et al